Transport
Roads & Maritime
Services

# Warrell Creek to Nambucca Heads

## Giant Barred Frog Monitoring Report
## Annual Report, Year One - Operational Phase

# Roads and Maritime Services | June 2019

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## Document Review

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**Cover Photo:** A gravid female giant barred frog (*Mixophyes iteratus*) recorded at Upper Warrell Creek during summer year one operational phase monitoring.

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# 1. Introduction

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog ponds, fauna underpasses, vegetated median, roadkill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program in accordance with the Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief (the Brief).

The following report details the methods and results of year one operational phase giant barred frog (*Mixophyes iteratus*) population monitoring. The objective of giant barred frog monitoring, as outlined in the Giant Barred Frog Management Strategy (GBFMS), is "to demonstrate through the life of the Project that mitigation has maintained or improved population sizes and habitat of the giant barred frog. The use of preconstruction, during construction and post construction monitoring to measure frog distribution, abundance and habitat quality with defined thresholds will be used to measure the overall performance of the mitigation" (Lewis 2014).

## 1.1 Background

The giant barred frog is listed as 'Endangered' under both the NSW *Biodiversity Conservation Act 2016* (BC Act) and Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The impact of the upgrade on giant barred frog was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010). Following identification of potential giant barred frog habitat during the Project environmental assessment, Lewis Ecological conducted targeted surveys (in November 2011 and January/February 2013) (Lewis 2014). A population of giant barred frog was subsequently confirmed at Upper Warrell Creek and a management strategy prepared (see Lewis 2014).

Measures proposed to manage impacts on giant barred frogs included: population monitoring, pre-clearing surveys, temporary frog fencing during construction, clearing supervision, dewatering procedures (tadpole surveys) and permanent frog exclusion fence. Population monitoring was recommended to occur within a 1km transect in spring, summer and autumn of Year 1 and 3 of the construction phase using the methods applied during pre-construction baseline surveys.

Pre-construction baseline surveys for giant barred frog were conducted between 20 September 2013 and 2 April 2014. The baseline surveys recorded 47 individuals, including 22 adults (11 females & 11 males), 8 sub-adults, and 8 juveniles. Based on these results the population of giant barred frog at the Upper Warrell Creek site was calculated as 45 adults (with a 1:1 sex ratio), 19 sub-adults, and 16 juveniles (Lewis Ecological 2014b). Geolink (2018) recalculated population size for baseline, year 1 and year 3 construction phase samples and obtained population estimates of 41 (2013/14), 7 (2015/16), and 8 (2017/18) respectively. The results suggest a substantial decline in population between 2013/14 and 2015/16.

During early construction work *Mixophyes* spp. tadpoles were recorded at Butchers Creek (Geolink 2015). There was some conjecture about the identification of tadpoles and targeted surveys for adult frogs and further consultation with frog specialists was undertaken in an attempt to confirm the identification. The final consensus was that the tadpoles were great barred frog (*Mixophyes fasciolatus*) and the giant barred frog was unlikely to occur at Butchers Creek (see Geolink 2015; Lewis 2015). Nonetheless, a precautionary approach was adopted and the Butchers Creek site was included in population monitoring (Geolink 2016). No giant barred frogs were recorded at Butchers Creek during the construction phase (Geolink 2018).

## 1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest.

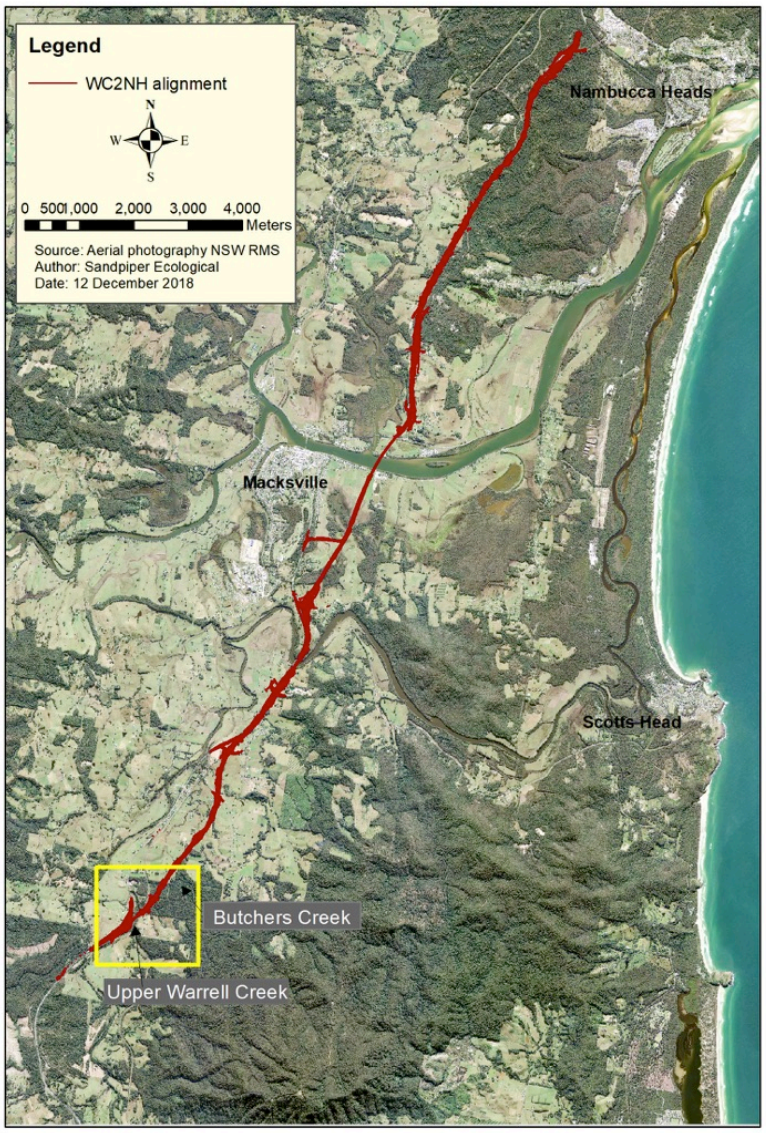


**Figure 1:** Location of giant barred frog sample sites in relation to the WC2NH alignment.

# 2. Methodology

## 2.1 Timing and weather conditions

Three monitoring events were conducted during year one operational phase giant barred frog monitoring; spring, summer and autumn. A rainfall trigger of 10mm, recorded at the southern or northern project compounds, was used to determine seasonal survey commencement. Spring surveys were conducted on 17 October 2018 after the rainfall trigger was recorded on 16 October 2018. Summer surveys were conducted on 25 and 26 February 2019 after the rainfall trigger occurred on 22 February 2019. Autumn surveys were conducted on 19 and 20 March 2019 after the rainfall trigger was recorded on 18 March 2019. Surveys were conducted between dusk and 1am.

Weather variables including rainfall (preceding and throughout surveys), relative humidity, temperature, dew point and wind speed were recorded at the start and finish of each survey at each site. Weather conditions for each survey were recorded at each site using a hand-held kestrel weather meter.

## 2.2 Frog survey

Frog surveys followed the method specified in the Brief and baseline population survey (Lewis 2014). The method involved:

1. Two ecologists conducted a nocturnal meandering foot-based traverse of each 50m survey zone on each side of the watercourse i.e. 40 zones at Upper Warrell Creek (20/side; Figure 2); and 16 zones at Butchers Creek (8/side; Figure 2).
2. Each ecologist was equipped with a 200-lumen spotlight and slowly traversed the riparian zone searching for frogs and listening for calls. Giant barred frog calls were broadcast through a 5-watt megaphone for five minutes within each zone. Both ecologists listened for call responses during and immediately after call broadcast.
3. All captured giant barred frogs were scanned with a Trovan Nanotransponder to determine if that frog had been previously pit-tagged. If the captured individual had not been pit-tagged and was deemed an adult (i.e. >60mm snout-vent length) a tag was inserted beneath the skin on the right side and the insertion hole sealed with vetbond. The insertion point was swabbed with disinfectant prior to the tag being inserted.
4. Data collected on each captured frog included:
    a. Survey zone (20x50m).
    b. Distance from the stream edge measured to the nearest 0.1m.
    c. Position within the microhabitat (i.e. under litter, above litter, exposed, on rock/log).
    d. Sex (male, female, unknown).
    e. Age class (adult=>60mm; sub-adult=40-60mm; juvenile=<40mm).
    f. Snout-vent length (mm).
    g. Weight (grams).
    h. Breeding condition:
        i. males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark) in accordance with the classification developed by Lewis (2014b);
        ii. females assessed based on whether they are gravid (i.e. egg bearing, with the typically adult weighing > 100 grams) or not gravid.
        iii. frogs with a snout vent length of <60 mm were classified as immature.

## 2.3 Tadpole survey

Tadpoles were sampled in spring and autumn only. In spring, a single tadpole trap (i.e. small bait trap) was set in each zone and baited with one slice of bread. Each trap was set for a minimum of three hours. Dip-netting for tadpoles was conducted by two ecologists within each zone. Dip-netting targeted accessible vegetated banks and rocky stream beds with a sufficient detritus layer. Only dip-netting was conducted during autumn surveys as per the brief.

## 2.4 Habitat assessment

Key habitat components in each survey zone are required to be sampled annually (i.e. once/year). Habitat sampling was conducted during the summer sample period. A senior ecologist conducted a meandering traverse of each zone at each site, including both banks. Habitat data recorded in each zone at each site included:

1. Land use: Description of existing land uses e.g. grazing, dairy, horticulture, conservation, private native forestry.
2. Broad vegetation type within the immediate riparian zone (primary stream bank): Riparian Rainforest, Dry Sclerophyll, Wet Sclerophyll, Sedgeland, Grassland or Cleared Land.
3. In stream physical characteristics including stream width and depth(metres), presence of pools and/or riffles, bed composition (sand, clay, rock, organic or other to be specified), and type of emergent vegetation, if present.
4. Stream bank characteristics including bank profile expressed as steep, benched or a gradual incline from the water's edge.
5. Foliage projective cover of overstorey, midstorey and ground layer vegetation on the stream bank.
6. Groundcover expressed as a percentage of vegetation, leaf litter, soil, and exposed rock.
7. Litter depth - Deep (>10 mm); Moderate (20-100 mm); Shallow (>0-20 mm); or Absent (0 mm).

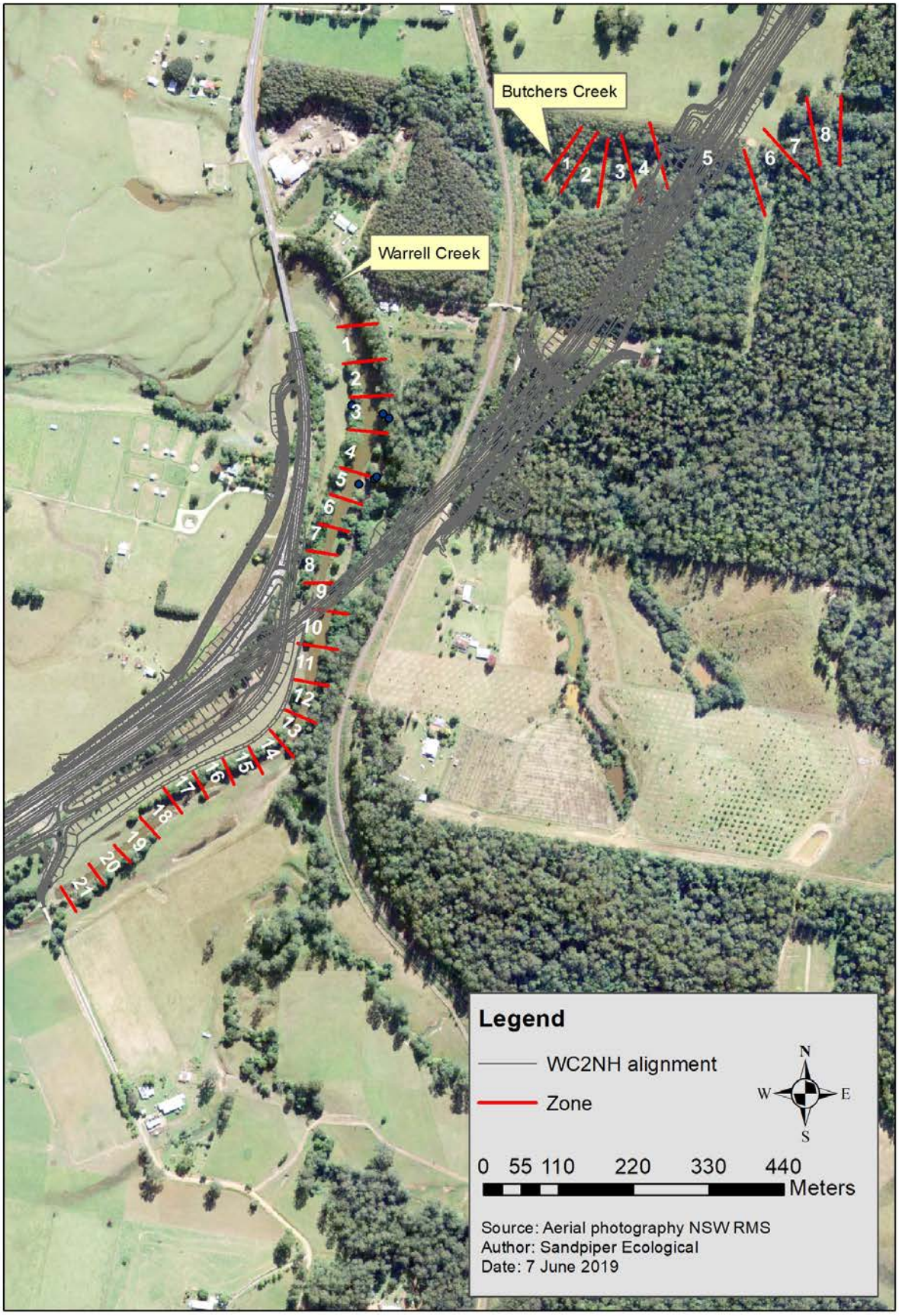


**Figure 2:** Survey zones within the Upper Warrell Creek and Butchers Creek sample sites.

## 2.5 Water quality

Water samples and field measurements were taken at approximate locations E: 489301 N: 6594447 at Upper Warrell Creek and E: 489642 N: 6594927 at Butchers Creek. Three samples were collected at each site and placed immediately into an esky. One sample was sealed immediately after collection for dissolved oxygen analysis and the other samples were used for hydrocarbons, and general physico-chemical parameters (see below). Samples were analysed by the Environmental Analysis Laboratory (EAL), a NATA accredited laboratory, at Southern Cross University. Water quality parameters measured included:

1. Heavy Metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.
2. Nutrients including Nitrogen (as N), Suspended Solids and Total Phosphorus.
3. Turbidity and dissolved oxygen.
4. Hydrocarbons from the following groups:
    a. Naphthalene group including TRH>C10-C16, TRH>C10-C16 less Naphthalene (F2), TRH>C16-C34, TRH>34-C40, TRH C6-C10 and TRH C6-C10 LESS BTEX (F1).
    b. BTEX group including Benzene, Ethylbenzene, m&p-Xylenes, o-Xylene, Toluene and Xylenes – total.

Field physicochemical measurements including Conductivity, pH, and Temperature, were measured using a Horiba Laqua PC110 portable water quality meter.

## 2.6 Population estimate

The modified Petersen-Lincoln index method (that is the Petersen-Lincoln method with the Chapman estimator) was used to calculate a population estimate for year one operational phase. The method follows that applied by Lewis (2014) and Geolink (2018). Juveniles, sub-adult, and non-captured individuals were not included in the equation which is consistent with the baseline and construction phase surveys. To be consistent with the baseline sample the analysis was based on summer and autumn data, although estimates for spring/summer and spring/autumn are provided for comparison. The equation and input data, included:

$$\hat{N} = \frac{(M+1)(C+1)}{(m+1)} - 1$$

*N* = population size
*M* = total captured in sample 1
*C* = total captured in sample 2
*m* = number recaptured in sample 2

## 2.7 Data summary and analysis

Rainfall data used to calculate long-term averages (1915-2015) was sourced from the Bureau of Meteorology (BOM) weather station at Macksville (no. 59018). Rainfall data for 2018/19 was sourced from the project's southern compound weather station at Albert Drive Donnellyville as the Macksville Station

ceased operating in 2015. Data for calculating recent (2015-2019) yearly rainfall averages was sourced from the BOM Smokey Cape station (no. 59030).

Individual frogs were identified by comparing PIT tag numbers recorded during this survey with those reported by Geolink (2018) and Lewis (2014). The number of individuals calculated for year one construction phase might be an underestimate as it does not include individuals captured during the first autumn sample (GeoLink 2018).

## 2.8 Temporal comparison

Data collected during year one operational phase were compared to the construction phase and baseline surveys to provide a temporal comparison of frog abundance. The number of giant barred frogs detected (i.e. captured and heard calling but not captured), and captured in each time period is presented using histograms. Population estimates derived during each survey are also compared.

# 3. Results

## 3.1 Abiotic data

Weather conditions were suitable for frog surveys during each seasonal survey (Table 1). Temperatures were above 18$^0$C, relative humidity was above 80%, and wind was generally absent or light (Table 1). Water levels at both sites were high (flood) in spring, low in summer and very low in autumn. Butchers Creek was flowing in spring, reduced to several pools of stagnant water in summer and reduced to one pool of stagnant water in spring. This was the outcome of a summer characterised by above average temperatures and below average rainfall (Figure 3).

**Table 1:** Weather conditions during each survey in year one monitoring. * 0 = no wind, 1 = rustles leaves, 2 = moves small branches, 3 = moves canopy. RH = Relative Humidity.

| Season | Site | Date | Start/Finish | Time | Rainfall (present) | Rainfall (prev 24hr) | Rainfall (prev 7 days) | Rainfall (prev 30 days) | RH | Temp (˚C) | Dew point | Wind* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring | Butchers Creek | 16/10/18 | Start | 2023 | Nil | 23.8mm | 112.2mm | 154.4mm | 94.5 | 19.5 | 18.5 | 0 |
| | | | Finish | 2210 | Moderate | | | | 100 | 18.9 | 19.4 | 0 |
| | Warrell Creek | 17/10/18 | Start | 1949 | Nil | 16.2mm | 128.4mm | 170.6mm | 100 | 20.7 | 21.3 | 2 |
| | | | Finish | 0049 | Moderate | | | | 100 | 20.2 | 21.8 | 2 |
| Summer | Butchers Creek | 25/2/19 | Start | 2007 | Nil | 1.6mm | 52.8mm | 112mm | 98.1 | 24.6 | 21.9 | 0 |
| | | | Finish | 2130 | Light shower | | | | 88.6 | 22.2 | 20.0 | 0 |
| | Warrell Creek | 25/2/19 | Start | 2140 | Nil | | | | 91.8 | 21.0 | 20.1 | 1 |
| | | | Finish | 2255 | Moderate | | | | 100 | 21.4 | 20.4 | 1 |
| | Warrell Creek | 26/2/19 | Start | 1958 | Nil | 1.0mm | 53.8mm | 113.8mm | 80.9 | 22.7 | 19.1 | 0 |
| | | | Finish | 2325 | Nil | | | | 92.8 | 19.2 | 17.9 | 0 |
| Autumn | Butchers Creek | 19/3/19 | Start | 1925 | Heavy showers | 30mm | 81.2mm | 177.4mm | 85.3 | 24.2 | 22.2 | 1 |
| | | | Finish | 2040 | Light | | | | 99.9 | 24.5 | 25.8 | 1 |
| | Warrell Creek | 19/3/19 | Start | 2050 | Nil | | | | 87.5 | 22.0 | 22.7 | 0 |
| | | | Finish | 2250 | Nil | | | | 100 | 22.1 | 21.3 | 1 |
| | Warrell Creek | 20/3/19 | Start | 1930 | Nil | 30mm | 81.2mm | 177.4mm | 93.8 | 22.8 | 21.2 | 0 |
| | | | Finish | 2300 | Nil | | | | 96.1 | 20.9 | 21.2 | 0 |

Surveys occurred during a period of below average rainfall in eastern Australia. Monthly rainfall over the monitoring period compared to the long-term average from the nearest Bureau of Meteorology (BOM) station (59018) shows that apart from October and December 2018, monthly rainfall was lower than the long-term average (Figure 3).

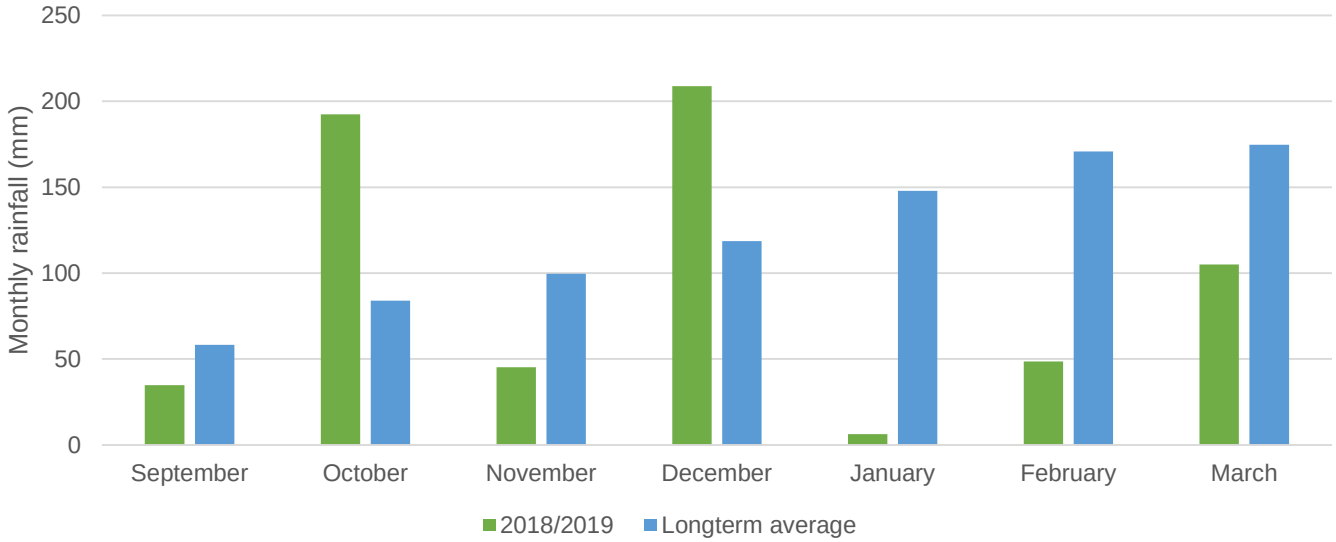


**Figure 3:** Monthly total rainfall recorded at the project southern compound weather station over the year one monitoring period against long term average recorded at the nearest BOM weather station – no. 59018.

## 3.2 Frog surveys

### 3.2.1 Spring survey

A total of 13.5 person hours were spent conducting nocturnal frog surveys in spring, 10 hours at Upper Warrell Creek and 3.5 hours at Butchers Creek. No giant barred frogs were recorded at Butchers Creek. Two giant barred frogs, one male and one female, were detected at Upper Warrell Creek (Table 2, Plate 1). One of these frogs was a new capture and the other a recapture. New capture Frog #1 was a female weighing 173g, a weight attributable to its gravid state (Plate 1). Re-captured Frog #2 was a male frog originally captured on 7 February 2018.

**Table 2:** Giant barred frogs captured at Upper Warrell Creek during spring 2018 monitoring.

| Upper Warrell Creek | Record 1 | Record 2 |
|---|---|---|
| Frog no. | 1 | 2 |
| Date | 17/10/18 | 17/10/18 |
| Zone | 8 | 6 |
| Creek side | N | N |
| GPS location | 489351, 6594448 | 489372, 6594537 |
| Distance from stream edge (nearest 0.1m) | 3.4 | 4.05 |
| Position in micro-habitat* | On leaf litter | On leaf litter |
| Sex* | F | M |
| Age* | Adult | Adult |
| S/V length (mm) | 101.5 | 77.1 |
| Weight | 173g | 67g |
| Breeding condition* | Gravid | Moderate |

| Upper Warrell Creek | Record 1 | Record 2 |
|---|---|---|
| Microchip ID (new or re-capture) | New: 991001000620130 | Recapture: 00078ABB9B |
| Original Date of capture | | 7/2/2018 |

*Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.
**Sex: Frogs >78mm were deemed female unless heard calling.
***Age: >60mm = adult, 40-60mm = sub, <40mm = Juv.
#Breeding: Males: colour of nuptial pads; light/moderate/dark/no colour. Females: Gravid, typically weighing >100g. Immature: SV length <60mm.

**Plate 1:** Frog #1 weighing 173g captured during spring surveys at Upper Warrell Creek.

### 3.2.2 Summer survey

A total of 12 person hours were spent conducting nocturnal frog surveys in summer, 9 hours and 24 minutes at Upper Warrell Creek and 2 hours and 46 minutes at Butchers Creek. No giant barred frogs were recorded at Butchers Creek. Four adult giant barred frogs, three males and one female, were recorded at Upper Warrell Creek (Table 3; Plate 2). Three of these were recaptures and the fourth individual could not be captured. The fourth individual was heard calling from the south side of Warrell Creek but could not be relocated when ecologists sampled the south bank.

Frog #3 was originally captured on 6 November 2017, whilst frog #2 and #4 were both captured in February 2018. Frog #4 was captured at a similar location to Frog #1, which was captured during the spring 2018 survey (Sandpiper Ecological 2018). Both individuals had similar S-V length, although Frog #1 was 32 grams heavier, a result attributed to its gravid state. It is possible that frogs #1 and #4 are the same individual.

All captured frogs were situated on the north bank downstream of the alignment, and the calling male was on the south bank also downstream of the alignment (Figure 5). Distance from the waters edge ranged from 1.1 to 8.3m. Male frogs were between 1.1 and 1.3m from the waters edge. Two individuals were recorded amongst clumps of grass and one was initially observed on top of leaf litter.

**Table 3:** Giant barred frogs captured during the summer survey at Upper Warrell Creek. NR = not recorded

| Upper Warrell Creek | Record 3 | Record 4 | Record 5 | Record 6 |
|---|---|---|---|---|
| Frog no. | 3 | 4 | 2 | 5 |
| Date | 26/2/19 | 26/2/19 | 26/2/19 | 26/2/19 |
| Zone | 4 | 5 | 6 | 7 |
| Creek side | N | N | N | S |
| GPS location | 489322, 6594426 | 489354, 6594451 | 489364, 6594543 | 489318, 6594556 |
| Distance from stream edge (nearest 0.1m) | 1.1m | 8.3m | 1.3m | NR |
| Position in micro-habitat* | Amongst grass | On leaf litter | Among clumps of Grass, some leaf litter on tributary | |
| Sex* | M - calling | F | M- calling | M-calling |
| Age* | Adult | Adult | Adult | Adult |
| S/V length | 83.8 | 101.5 | 74.8 | |
| Weight | 85g | 141g | 76g | |
| Breeding condition* | Moderate | Gravid | Moderate-dark | |
| Microchip ID (new or re-capture) | Recapture: 00077E8FEF | Recapture: 00078ABBF2 | Recapture: 00078ABB9B | |
| Original date of capture | 6/11/2017 | 5/2/2018 | 7/2/2018 | |
| Recapture dates | | | 17/10/2018 | |

*Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.
**Sex: Frogs >78mm were deemed female unless heard calling.
***Age: >60mm = adult, 40-60mm = sub, <40mm = Juv.
#Breeding: Males: colour of nuptial pads; light/moderate/dark/no colour. Females: Gravid, typically weighing >100g. Immature: SV length <60mm.

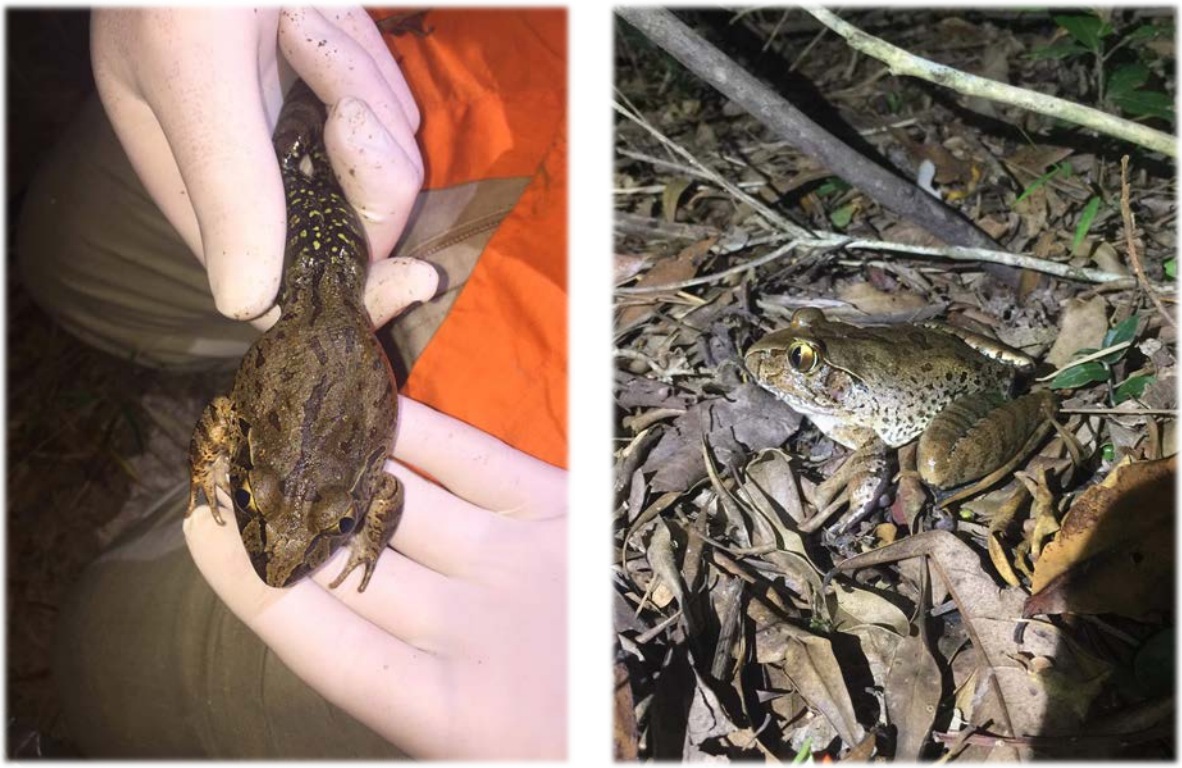

**Plate 2:** Male (L) and female (R) giant barred frogs recorded at Upper Warrell Creek during the summer survey.

### 3.2.3 Autumn survey

A total of 12 person hours and 15 minutes were spent conducting nocturnal frog surveys in autumn, 11 hours at Upper Warrell Creek and 1 hour and 15 minutes at Butchers Creek. No giant barred frogs were detected at Butchers Creek.

Six giant barred frogs were detected at Upper Warrell Creek during autumn surveys. Of these, three were male, two female, and one (Frog #6) unknown sub-adult with a snout/vent length of 45.7mm (Plate 3). All other frogs were adult frogs. The weight of Frogs #4 and #8 suggests they were gravid at the time of capture (Table 4, Plate 3). Frog records #9 and #12 were recaptures, the remaining frogs were new individuals. Frog #4 was captured in summer 2019 and originally captured and tagged on 5 February 2018. Frog #3 was captured in summer 2019 and originally tagged and captured on 6 November 2017. Frog #6 was captured up-stream of the alignment, whilst all other individuals were captured down-stream (Figure 5). Frog #6 was not tagged due to its small size.

**Table 4:** Giant barred frogs detected during autumn surveys at Upper Warrell Creek.

| Upper Warrell Creek | Record 7 | Record 8 | Record 9 | Record 10 | Record 11 | Record 12 |
|---|---|---|---|---|---|---|
| Frog no. | 5 | 6 | 4 | 7 | 8 | 3 |
| Date | 19/3/19 | 19/3/19 | 20/3/19 | 20/3/19 | 20/3/19 | 20/3/19 |
| Zone | 3 | 17 | 5 | 6 | 5 | 5 |
| Creek side | Y | Y | Y | Y | Y | Y |
| GPS location | 489323, 6594584 | 489057, 6593987 | 489342, 6594424 | 489331, 6594419 | 489305, 6594377 | 489320, 6594428 |
| Distance from stream edge (nearest 0.1m) | 1.54 | 5.0 | 4.42 | 1.3 | 3.6 | 0.8 |
| Position in micro-habitat* | Leaf litter, grazed paddock | Leaf litter, water gum | Leaf litter | Leaf litter, water gum overstorey | Leaf litter with water gum overstorey | In Paspalum, water gum overstorey |
| Sex* | M-calling | UK | F | M-calling | F | M-calling |
| Age* | Adult | Sub adult | Adult | Adult | Adult | Adult |
| S/V length (mm) | 75.9 | 45.7 | 99.5 | 73.2 | 92.5 | 81.8 |
| Weight | 53g | 11.5g | 165g | 57g | 116g | 85g |
| Breeding condition* | Moderate | NA | Gravid | Light-mod | Gravid | Moderate |
| Microchip ID (new or re-capture) | New: 991001000620121 | Not tagged. | Recapture: 00078ABBF2 | New: 991001000620125 | New: 991001000620122 | Recapture: 00077E8FEF |
| Original date of capture | | | 5/2/2018 | | | 6/11/2017 |
| Recapture dates | | | 26/2/2019 | | | 26/2/2019 |

*Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.
**Sex: Frogs >78mm were deemed female unless heard calling.
***Age: >60mm = adult, 40-60mm = sub, <40mm = Juv.
#Breeding: Males: colour of nuptial pads; light/moderate/dark/no colour. Females: Gravid, typically weighing >100g. Immature: SV length <60mm.

**Plate 3:** Adult gravid female weighing 165g (L). A sub-adult giant barred frog measuring 45.7mm S/V length (R) detected in autumn surveys at Upper Warrell Creek.

### 3.2.4 Year one survey summary

Eight giant barred frogs were detected (i.e. captured and heard calling) over three survey events at Upper Warrell Creek during year one operational phase monitoring (Figures 4 & 5). No giant barred frogs were recorded at Butchers Creek. All frogs, except sub-adult Frog #6, were detected down-stream of the alignment. All frogs except Frog #4 (91%) were located within 5m of the creek edge. Of the eight individuals captured, four were male and three female, with the sub-adult (Frog #6) recorded as sex unknown. Four new individuals were captured and tagged in year one operational phase surveys. The oldest recaptured frog was Frog #3 which was originally tagged on 6 November 2017. No frogs from baseline or year one construction phase surveys were captured. Gravid females were recorded during each sample. Other frog species recorded at both sites during all surveys are listed in Appendix B.

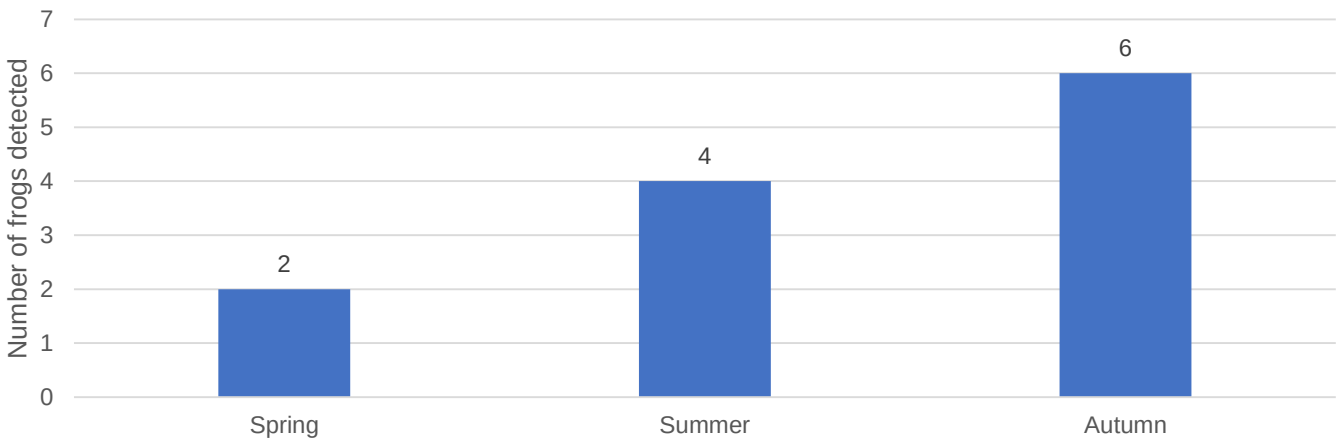


**Figure 4:** Giant barred frogs detected at Upper Warrell Creek over three monitoring events during year one operational phase monitoring.

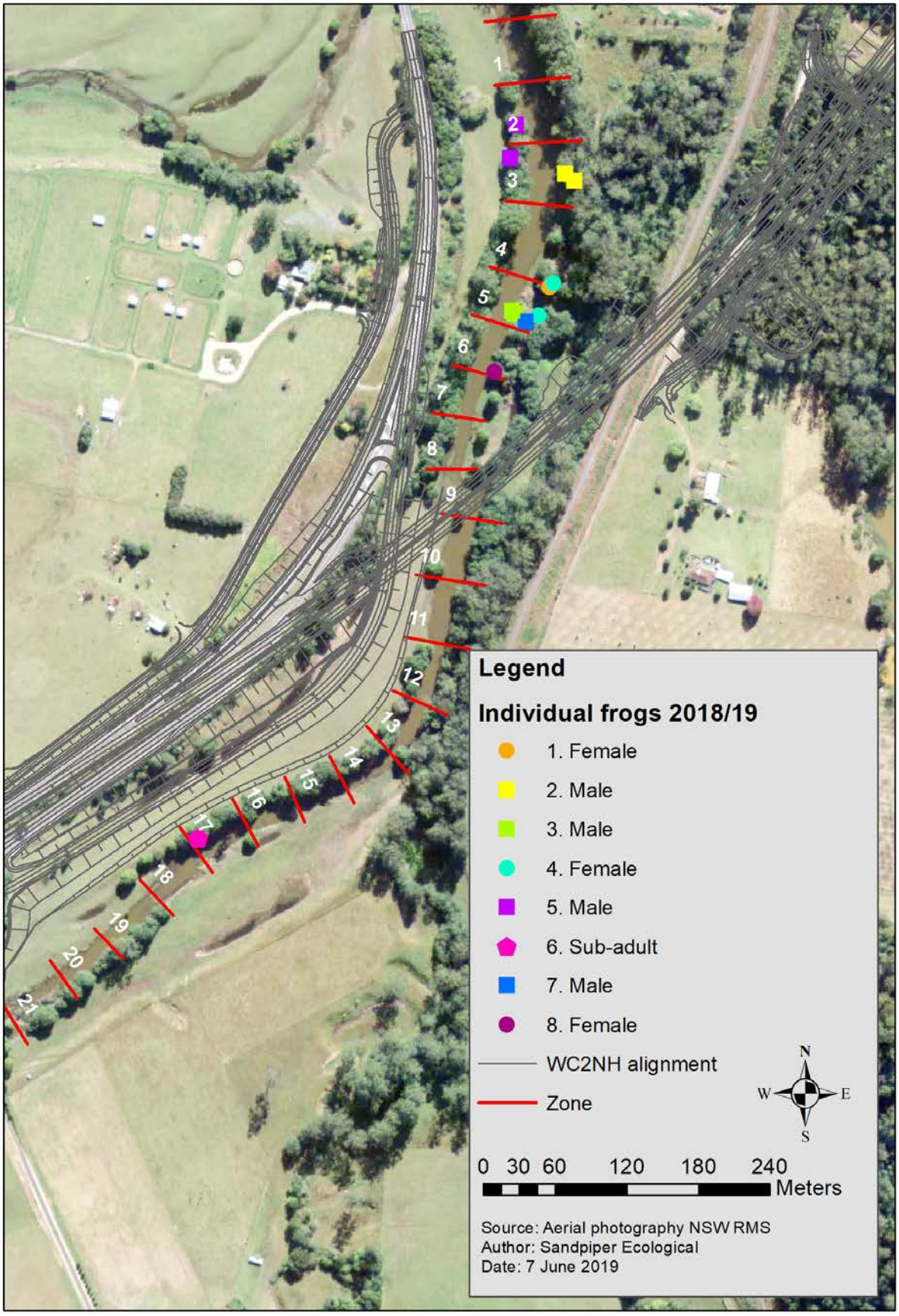


**Figure 5:** Location of year one operational phase giant barred frog records at Upper Warrell Creek.

### 3.2.5 Population estimate

The adult giant barred frog population estimate for Upper Warrell Creek in year one operational phase was seven (+/- SE 2.45) with a 95% confidence interval of 4.8 (Table 5). This suggests an adult population range of between two and 12 frogs occupying the 1km transect at Upper Warrell Creek. As seven adult frogs were recorded in year one the range for population size is more accurately presented as 7-12 individuals. No population estimate was calculated for Butchers Creek as no giant barred frogs have been recorded at that site.

**Table 5:** Population estimate, standard error and 95% confidence interval after the conclusion of year one operational phase giant barred frog monitoring at Upper Warrell Creek.

| | |
|---|---|
| Population estimate | 7 |
| Standard error | 2.45 |
| 95% confidence interval | 4.8 |

## 3.3 Tadpole surveys

No giant barred frog tadpoles were detected at either Butchers Creek or Upper Warrell Creek during year one operational phase monitoring.

## 3.4 Habitat

### 3.4.1 Upper Warrell creek

Habitat at Upper Warrell Creek ranged from grassland/pasture to moderate quality riparian and wet sclerophyll forest with a dense litter layer (Appendix B). Parts of the Upper Warrell Creek study area contained fragmented and grazed riparian forest. Whilst some areas appear rarely used by cattle there is evidence of disturbance (i.e. clearing, weed infestation) throughout the study area. Vegetation does not extend beyond the creek bank/riparian zone. The width of riparian vegetation ranged from nil to 40m. Leaf litter cover ranged from high (>75%) in areas with an intact riparian zone to low (<10%) in cleared and grazed areas. One notable aspect of concern was growth of pigeon grass (S*etaria sphacelata*) and broad-leaved paspalum (*Paspalum mandiocanum*) on the north bank in zone 5. Whilst giant barred frogs have been recorded in broad-leaved paspalum, pigeon grass may create a barrier to movement when it occurs in dense clumps. The bank profile is characterised by a vertical face (<1m) at the waters edge and then a steep slope that ranged from 5 to 40m in length. Undercuts were recorded at the waters edge in several locations.

Weeping lilly pilly (*Waterhousia floribunda*) and flooded gum (*Eucalyptus grandis*) dominated the overstorey and mat rush (*Lomandra longifolia*) dominated the ground layer. Mat rush occurred in small clumps along the entire waters edge. Leaf litter depth, in areas of intact riparian forest, ranged from 40 to 100mm deep and total vegetation cover from 50 to 90%. Vegetation cover remained high in cleared areas due to dense grass cover.

### 3.4.2 Butchers Creek

Habitat at Butchers Creek varied substantially across the study area (Appendix B). During summer, the creek bed was dry except for a single pool in Zone 2. Habitat west of the alignment was highly degraded with recent (September/October) clearing to the creek bank. The dominant riparian species was camphor laurel (*Cinnamomum camphora*) with some small-leaved privet (*Ligustrum sinense*), callicoma (*Callicoma serratifolia*) and red ash (*Alphitonia excelsa*). Habitat east of the alignment was characterised by wet sclerophyll forest that extended well beyond the riparian zone. The creek bed consisted of rock and gravel with a steep bank and gravel bars. Leaf litter cover on the creek bank varied from 25 to 80% and ground vegetation cover from 10 to 60%. Despite the degree of fragmentation total vegetation cover was high, with only one of 16 sample sites receiving a cover score less than 40%. Habitat at Butchers Creek did not contain the moist microclimate that is typical of many giant barred frog habitats, which coupled with the ephemeral stream flow makes the site largely unsuitable for the target species.

## 3.5 Water quality

Most water quality parameters were within the ANZECC trigger values for freshwater ecosystems in south eastern Australia (Table 6). Exceptions were pH at Butchers Creek during summer and autumn surveys, and total Phosphorus at Upper Warrell Creek in spring and summer. The low dissolved oxygen levels recorded at both sites in spring and summer are attributed to a laboratory error and is not regarded as accurate. Turbidity was below the ANZECC threshold at both sites although the higher spring level is attributed to elevated stream flow during that sample. The higher nitrogen level recorded in spring is also attributed to higher stream flow. Both nitrogen and phosphorus values exceeded thresholds during the 2017/18 sample period (GeoLink 2018). Benzene, toluene, ethylbenzene and xylene levels and total recoverable hydrocarbons were within normal parameters during each sample.

**Table 6:** Results of water sample analysis for Upper Warrell creek and Butchers Creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000). *Laboratory error; not regarded as accurate measurement.

| Parameter | Spring | | Summer | | Autumn | | ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection) |
|---|---|---|---|---|---|---|---|
| | Warrell Creek | Butchers Creek | Warrell Creek | Butchers Creek | Warrell Creek | Butchers Creek | |
| Temperature ($^0$C) | 19.6 | 18.5 | No data | No data | 23.4 | 20.8 | |
| pH | 6.7 | 6.9 | 6.59 | 6.12 | 6.63 | 6.39 | 6.5-8.0 |
| Conductivity (us/cm) | 256 | 110 | 292 | 179 | 291 | 159.1 | 125-2200 |
| Dissolved oxygen (mg/L $O_2$) | 8.4 | 9 | 3.5* | 6.7* | No data | No data | 9-10.5 |
| Total Suspended Solids (mg/L) | 9 | 1 | 3 | 1 | 3 | 194 | |
| Turbidity (NTU) | 18 | 17 | 3.4 | 1.5 | 4 | 1.2 | 6-50 |
| Total Phosphorus (mg/L P) | 0.04 | 0.02 | 0.03 | 0.01 | 0.02 | 0.02 | 0.025 |
| Total Nitrogen (mg/L N) | 0.49 | 0.19 | 0.29 | 0.10 | 0.24 | 0.15 | 0.35 |
| BTEX | | | | | | | |
| Benzene (µg/L or ppb) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 950 |
| Toluene (µg/L or ppb) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | ID |
| Ethylbenzene (µg/L or ppb) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | ID |
| m+p-Xylene (µg/L or ppb) | <1 | <1 | <1 | <1 | <1 | <1 | 200 |
| o-Xylene (µg/L or ppb) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 350 |
| Naphthalene (µg/L or ppb) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 16 |
| Total Recoverable Hydrocarbons (TRH) | | | | | | | |
| C6-C9 Fraction (µg/L or ppb) | <40 | <40 | <40 | <40 | <40 | <40 | ID |
| C10-C14 Fraction (µg/L or ppb) | <50 | <50 | <50 | <50 | <50 | <50 | ID |
| C15-C28 Fraction (µg/L or ppb) | <200 | <200 | <100 | <100 | <100 | <100 | ID |
| C29-C36 Fraction (µg/L or ppb) | <200 | <200 | <50 | <50 | <50 | <50 | ID |
| C10-C16 Fraction (µg/L or ppb) | <60 | <60 | <60 | <60 | <60 | <60 | ID |
| C10-C16 less Naphthalene Fraction (µg/L or ppb) | <60 | <60 | <60 | <60 | <60 | <60 | ID |
| C16-C34 Fraction (µg/L or ppb) | <500 | <500 | <200 | <200 | <200 | <200 | ID |
| C34-C40 Fraction (µg/L or ppb) | <500 | <500 | <100 | <100 | <100 | <100 | ID |
| Sum C10-C36 Fraction (µg/L or ppb) | No data | No data | <100 | <100 | <100 | <100 | ID |

# 3.6 Temporal comparison

## 3.6.1 Frog surveys

The total number of giant barred frogs recorded declined substantially between baseline and year one of the construction surveys. A more gradual decline is evident from year one construction phase, where 16 detections occurred, to year one operational phase, where 12 detections occurred (Figure 6).

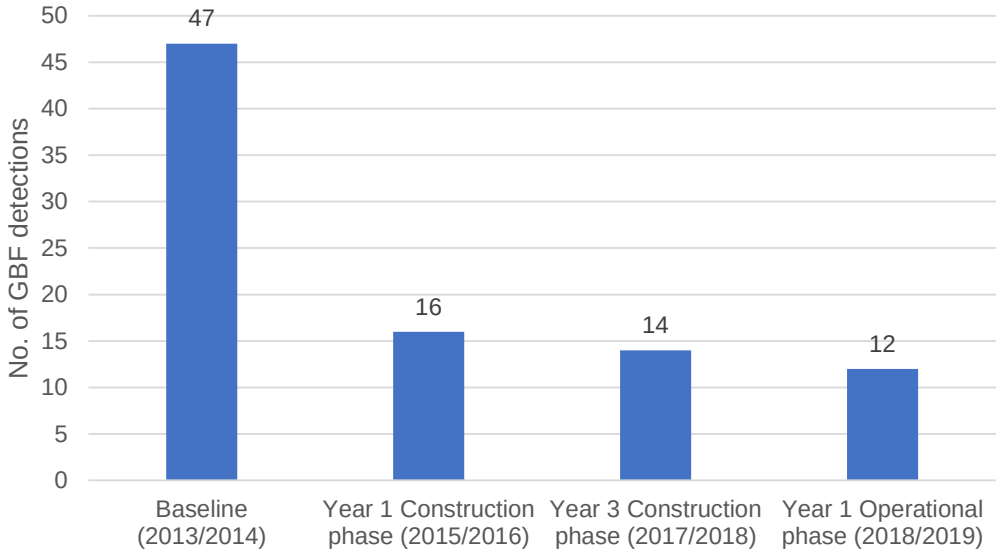


**Figure 6:** Total number of giant barred frog recorded in each of four sample periods at Upper Warrell Creek. Values include multiple recaptures of the same individual and calling males that were not captured.

The total number of individuals captured between baseline and year one construction phase surveys declined from 38 to eight and has remained stable over the construction and year one operational phase (Figure 7).

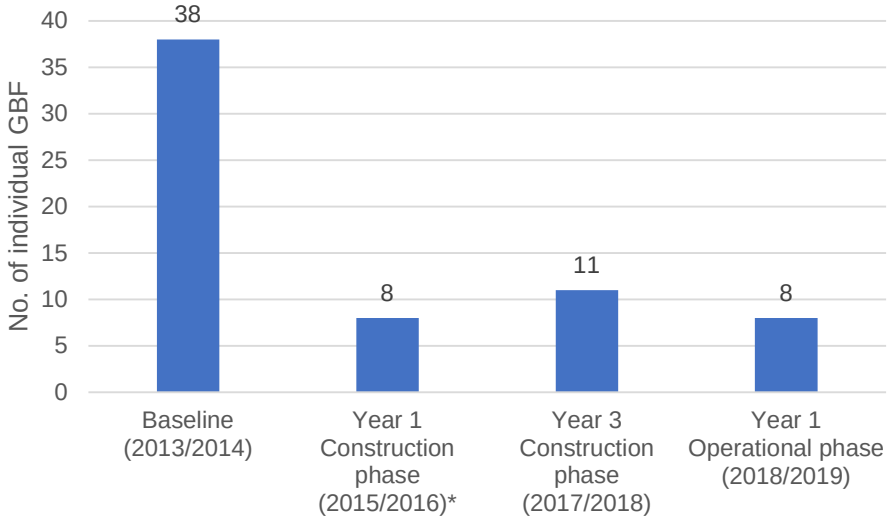


**Figure 7:** Number of individual giant barred frogs recorded over four sample events at Upper Warrell Creek. *Year one construction phase number may be an underestimate as it does not include frogs recorded in autumn 2015 (GeoLink 2018).

## 3.6.2 Population estimate

Comparison of adult population estimates across the four sample periods shows a decline at the Upper Warrell Creek site (Table 7). The population estimate of 43 adult frogs in 2013/14 declined to seven in year one of the construction phase with estimates of eight and seven recorded in year 3 construction phase and year one operation phase respectively (Table 7, Figure 8).

**Table 7:** Population estimates of adult giant barred frog at Upper Warrell Creek prior to construction (Lewis 2014), during construction (GeoLink 2018) and operational phase (Sandpiper 2019). GBF = giant barred frog.

| Parameter | Baseline (2013/2014) | Year 1 Construction phase (2015/2016) | Year 3 Construction phase (2017/2018) | Year 1 Operational Phase (2018/2019) |
|---|---|---|---|---|
| GBF population estimate | 43 | 7 | 8 | 7 |
| Standard error | 13.59 | 1.41 | 1.76 | 2.45 |
| 95% confidence interval | 26.6 | 9.77 | 10.46 | 4.8 |


**Figure 8:** Adult population estimates (+ standard error) at Upper Warrell Creek during baseline (Lewis 2014), construction phase (GeoLink 2018) and year one operational phase monitoring (this study).

# 5. Discussion

## 5.1 Frog surveys

In year one operational phase monitoring no giant barred frogs were recorded at Butchers Creek, which is consistent with both pre-construction and construction phase surveys. Survey results at Upper Warrell Creek demonstrate that giant barred frogs continue to persist at that site. With a total of eight individuals recorded and an adult population estimate of 7 (± 2.45) individuals the population has remained relatively stable since year one construction phase. The substantial decline in population size from the baseline survey to the first construction phase sample suggests a stochastic event or a combination of factors negatively influenced the population.

Interpreting the apparent decline in abundance at Upper Warrell Creek should be informed by broader understanding of amphibian population dynamics. That is, frogs mostly exist in meta-populations that feature highly variable sub-populations which can fluctuate greatly over time (Alford & Richards 1999). Archetypally, populations may experience years of decline punctuated by years of high recruitment when environmental conditions are favourable (Green 2003). Two populations of Fleay's barred frog (*M. fleayi* - a congener of the giant barred frog) reportedly recovered over a seven-year period after suffering a significant decline in abundance (Newell *et al.* 2013).

The baseline population estimate may have been associated with a particularly good breeding season the preceding year. Lewis (2014) alludes to this and suggests that the adult population estimate derived from surveys in 2013/14 was an artefact of a good breeding season on 2012/13 when several flood events would have enabled frogs to breed. The high number of juveniles and sub-adults recorded (n = 16) during the baseline support the likelihood of successful breeding in 2012/13.

Year one operational phase monitoring was typified by below average rainfall with anomalies in October and December 2018 when above average rainfall was recorded. These anomalies may have contributed to the higher detection rates in the summer and autumn surveys where more calling males and a sub-adult individual were detected. Of the seven years from 2012 to 2018, six had below average rainfall, and 2015 was the only year with above average rainfall. Even with above average rainfall in 2015, the giant barred frog population at Upper Warrell Creek declined substantially from the baseline sample, which suggests other factors have affected the population. Reproductive success in giant barred frog populations may be more influenced by the timing of rain events in the breeding cycle than the average amount of rain received in a year. For example, good spring rain, with follow-up rain in summer and autumn, would provide better breeding conditions than above average rain in late autumn.

There is a paucity of basic ecological information about the factors that underlie amphibian population cycles, and such information is critical for determining whether population variations are natural, and short or long-term (Whiteman and Wissinger 2005). Giant barred frog fits the definition of an r-selected species, a species that matures rapidly, has an early age of first reproduction, has a relatively short lifespan, a large number of offspring at a time, and few reproductive events (Pianka 1970). An r-selected breeding strategy may partly explain the relatively high number of frogs recorded during baseline sampling.

This analysis considered, the causes of population decline after baseline surveys, particularly of the adult frog population, warrant further assessment. Natural attrition from predation, climate variability, and disease may have contributed to the decline, and many of the juvenile and sub-adult individuals recorded in 2013/14 may not have reached maturity. Little is known about the home range and dispersal capabilities of

giant barred frog, but it is reasonable to assume some individuals dispersed from the study area or were washed down stream during flood events.

The clearing of riparian vegetation and construction of a temporary causeway and temporary frog fencing would have reduced the habitat available to individuals in Zones 8, 9 and 10. Twenty-three giant barred frogs were recorded in these zones during baseline surveys. The zones were characterised by a flatter bank profile, narrow stream width, and a back channel and may have contained important foraging and breeding habitat (Lewis & Rohweder 2005). Indeed, the presence of 19 individuals in Zone 8 during the baseline suggests it contained high quality breeding habitat. Changes in vegetation, hydrology, and stream morphology during and post construction may have reduced habitat suitability and influenced breeding success and dispersal. Thereby contributing to a decline in frog abundance. The impact area is contrasted by the surrounding zones, which are characterised by steep banks, deep water and, in places, fragmented and narrow riparian vegetation.

Habitat fragmentation and clearing reduces habitat suitability for giant barred frogs by removing the overstorey, which provides leaf litter and cover that are critical for creating a moist ground layer with abundant organic material. Clearing also enables weeds and grasses to become established that inhibit frog movement. This is evident within the alignment at Upper Warrell Creek, and immediately to the west where pigeon grass (*Setaria* spp), broad-leaved paspalum (*Paspalum mandiocanum*), and knotweed (*Persicaria* spp.) dominate the ground layer.

## 5.2 Effectiveness of Mitigation Measures

### 5.2.1 Frog exclusion fencing

No giant barred frogs were detected as roadkill during spring, summer or autumn roadkill surveys at WC2NH (Sandpiper 2019). No incidental road killed giant barred frogs were detected on local roads in the area. The permanent frog exclusion fence is intact and functional. Movement of giant barred frogs from the creek onto the road is unlikely given the amount of scour rock and absence of vegetation cover.

### 5.2.2 Maintain habitat connectivity

No evidence of upstream or downstream movement by giant barred frogs was recorded during the year one surveys. The potential for movement will improve as riparian vegetation re-establishes.

# 6. Recommendations

- Continue giant barred frog monitoring in year three of the operational phase, as per the ecological and water quality monitoring brief.
- Dip-netting for tadpoles should target back channels and pools that contain more suitable tadpole habitat.
- Habitat remediation work involving control of pigeon grass, broad-leaved paspalum and knotweed in conjunction with additional planting of mat rush, and water gum is warranted in Zones 8, 9 and 10 to improve habitat connectivity.
- Consideration should be given to controlling pigeon grass, broad-leaved paspalum, and knotweed in Zone 4 and 5 to improve habitat connectivity.

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# Appendix A – Habitat data

**Table A1:** Habitat data collected in 21 zones at Upper Warrell Creek

| Zone | Bank | Land use (E&W) | Broad veg community (E&W) | In-stream physical characteristics (logs, boulders etc) | Stream width | Stream depth | Presence of pools or riffles | Bed composition | Emergent veg |
|---|---|---|---|---|---|---|---|---|---|
| 1 | N | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| | S | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| 2 | N | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| | S | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| 3 | N | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| | S | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| 4 | N | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| | S | Agriculture | Riparian | Rare snags & logs, knotweed & mat rush at waters edge, water lily | 20-25 | 1-2m | No | Unknown | Water lily |
| 5 | N | Agriculture | Riparian | Snags, mat rush at waters edge, water lily, undercut bank | 20 | 1-2m | No | Unknown | Water lily, occasional |
| | S | Agriculture | Riparian | Snags, mat rush at waters edge, water lily, undercut bank | 20 | 1-2m | No | Unknown | Water lily, occasional |
| 6 | N | Road reserve | Riparian | Logs, snags, water lily, mat rush at waters edge | 15 | 1-2m | No | Unknown | Water lily |
| | S | Agriculture | Riparian | Logs, snags, water lily, mat rush at waters edge | 15 | 1-2m | No | Unknown | Water lily |
| 7 | N | Road reserve | Riparian | Logs, snags, water lily, mat rush at waters edge | 15 | 1-2m | No | Unknown | Water lily |
| | S | Agriculture | Riparian | Logs, snags, water lily, mat rush at waters edge | 15 | 1-2m | No | Unknown | Water lily |
| 8 | N | Road reserve | Grassland | Boulders, logs, waterlily, juncus, schoenoplectus | 8 | 1m | Yes | Silt& gravel | Water lily, water primrose |
| | S | Road reserve | Grassland/ riparian | Boulders, logs, waterlily, juncus, schoenoplectus | 8 | 1m | Yes | Silt& gravel | Water lily, water primrose |
| 9 | N | Road reserve | Riparian/cleared | Boulders, logs, waterlily, juncus, schoenoplectus | 8 | 1m | Yes | Silt& gravel | Water lily, water primrose |
| | S | Road reserve | Grassland/ riparian | Boulders, logs, waterlily, juncus, schoenoplectus | 8 | 1m | Yes | Silt& gravel | Water lily, water primrose |
| 10 | N | Agriculture | Riparian | Occasional logs & snags | 15 | 1-2m | Yes | Unknown | Water lily, water primrose |
| | S | Road reserve | Grassland | Occasional logs & snags | 15 | 1-2m | Yes | Unknown | Water lily, water primrose |
| 11 | N | Agriculture | Riparian | Snags, logs, aquatic vegetation | 12 | 1-2m | No | Unknown | Water lily |
| | S | Road reserve | Grassland | Snags, logs, aquatic vegetation | 12 | 1-2m | No | Unknown | Water lily |
| 12 | E | Agriculture | Riparian | Occasional logs, water lily, snags | 15 | 1-2m | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs, water lily, snags | 15 | 1-2m | No | Unknown | Water lily |

| Zone | Bank | Land use (E&W) | Broad veg community (E&W) | In-stream physical characteristics (logs, boulders etc) | Stream width | Stream depth | Presence of pools or riffles | Bed composition | Emergent veg |
|---|---|---|---|---|---|---|---|---|---|
| 13 | E | Agriculture | Riparian | Occasional logs, water lily, snags | 13 | 1-2m | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs, water lily, snags | 13 | 1-2m | No | Unknown | Water lily |
| 14 | E | Agriculture | Grassland | Occasional logs, water lily (capensis & indica), elodea | 13 | 1m | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs, water lily (capensis & indica), elodea | 13 | 1m | No | Unknown | Water lily |
| 15 | E | Agriculture | Grassland | Occasional logs, clumps of mat rush, water lily, knot weed | 11 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs, clumps of mat rush, water lily | 11 | Unknown | No | Unknown | Water lily |
| 16 | E | Agriculture | Grassland | Occasional logs, clumps of mat rush, water lily, knot weed | 11 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs, clumps of mat rush, water lily | 11 | Unknown | No | Unknown | Water lily |
| 17 | E | Agriculture | Grassland | Occasional logs, clumps of mat rush, water lily | 11 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs, clumps of mat rush, water lily | 11 | Unknown | No | Unknown | Water lily |
| 18 | E | Agriculture | Riparian | Occasional logs; grass to water level | 5 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Riparian | Occasional logs; grass to water level | 5 | Unknown | No | Unknown | Water lily |
| 19 | E | Agriculture | Riparian | Occasional logs; grass to water level | 9 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Grassland | Occasional logs; grass to water level | 9 | Unknown | No | Unknown | Water lily |
| 20 | E | Agriculture | Riparian | Occasional logs; grass to water level | 9 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Grassland | Occasional logs; grass to water level | 9 | Unknown | No | Unknown | Water lily |
| 21 | E | Agriculture | Riparian | Occasional logs; grass to water level | 9 | Unknown | No | Unknown | Water lily |
| | W | Road reserve | Grassland | Occasional logs; grass to water level | 9 | Unknown | No | Unknown | Water lily |

**Table A2:** Habitat data collected in 21 zones at Upper Warrell Creek

| Zone | Bank | Stream bank characteristics | Bank profile | Bank vegetation cover (%) | Groundcover composition (% of vegt, litter, rock, bare earth) | Depth of leaf litter |
|---|---|---|---|---|---|---|
| 1 | N | Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana, | Steep 20m | 65 | Mat rush, lantana, shrubs | 40-50mm |
| | S | Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge, | Undercuts, vertical 0.5m, steep 4m, moderate 5m | 80 | Mat rush, fishbone fern, vines | 75-100mm |
| 2 | N | Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana, | Steep 20m | 65 | Mat rush, lantana, shrubs | 40-50mm |
| | S | Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge, | Undercuts, vertical 0.5m, steep 4m, moderate 5m | 80 | Mat rush, fishbone fern, vines | 75-100mm |
| 3 | N | Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana, | Steep 20m | 65 | Mat rush, Carex, BL paspalum | 40-50mm |
| | S | Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge, | Undercuts, vertical 0.5m, steep 4m, moderate 5m | 80 | Mat rush, fishbone fern, vines | 75-100mm |
| 4 | N | Immediate bank cleared - BL paspalum & igloo grass within 15m of bank, riparian on slope, waterhousia, flooded gum 40m, dense ground cover on immediate bank | Flat for 20m, Steve 40m | 25 | BL paspalum, pigeon grass, occasional mat rush | 50mm |
| | S | Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge, | Undercuts, vertical 0.5m, steep 4m, moderate 5m | 80 | Mat rush, fishbone fern, vines | 75-100mm |
| 5 | N | Riparian 40m incl side channel, waterhousia, mat rush, BL paspalum, SL privet, dense shrub & ground layer | Vertical 2m, moderate 20m | 60 | Mat rush, BL paspalum, lantana | 40mm |
| | S | Intact riparian zone 15m wide from water to top of bank, waterhousia, some lantana, mat rush at waters edge | Vertical 0.5m, steep 13m | 55 | Mat rush, shrubs, lantana, | 100mm |
| 6 | N | Riparian 40m incl side channel, waterhousia, mat rush, BL paspalum, SL privet, dense shrub & ground layer | Vertical 2m, moderate 20m | 60 | Mat rush, BL paspalum, lantana | 40mm |
| | S | Established riparian zone 13m, waterhousia, good litter cover | Vertical 0.75m, steep 12m | 70 | Leaf litter, mat rush at waters edge, occasional vines & low shrubs | 30mm |
| 7 | N | Established riparian zone 13m, waterhousia, good litter cover | Vertical 0.75m, steep 12m | 70 | Leaf litter, mat rush at waters edge, occasional vines & low shrubs | 30mm |
| | S | Established riparian zone 13m, waterhousia, good litter cover | Vertical 0.75m, steep 12m | 70 | Leaf litter, mat rush at waters edge, occasional vines & low shrubs | 30mm |
| 8 | N | Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge | Flat 20m | 35 | Knotweed, Schoenoplectus, juncus, cyperus spp, Carex | <10mm |
| | S | Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge | Flat 20m | 35 | Knotweed, Schoenoplectus, juncus, cyperus spp, Carex | <10mm |
| 9 | N | Scour protection, flat bank profile under bridge, 20m riparian zone, waterhousia, mat rush at waters edge, | Flat beneath bridge, moderate 20m | 55 | Mat rush, low shrubs | 50mm |
| | S | Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge | Flat 20m | 35 | Knotweed, Schoenoplectus, juncus, cyperus spp, Carex | <10mm |
| 10 | N | Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey | Vertical 1m, moderate 15m, steep 10m | 80 | Mat rush, BL paspalum, shrubs | 40mm |
| | S | Scour protection (under bridge), knot weed, pigeon grass, occasional waterhousia | Vertical 1.5m, mod slope 3m | 90 | Knot weed, pigeon grass, BL paspalum | 20mm |
| 11 | N | Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey | Vertical 1m, moderate 15m, steep 10m | 80 | Mat rush, BL paspalum, shrubs | 40mm |
| | S | Cleared grassland, pigeon grass, and knotweed to waters edge, sparse Schoenoplectus | Flat 3m, vertical 1m | 95 | Pigeon grass, knot weed | 20mm |

| Zone | Bank | Stream bank characteristics | Bank profile | Bank vegetation cover (%) | Groundcover composition (% of vegt, litter, rock, bare earth) | Depth of leaf litter |
|---|---|---|---|---|---|---|
| | | mucronatus. | | | | |
| 12 | E | Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey | Vertical 1m, moderate 15m, steep 10m | 80 | Mat rush, BL paspalum, shrubs | 50mm |
| | W | Fragmented riparian/grassland, waterhousia, pigeon grass, knotweed & mat rush at waters edge | Vertical 1m, steep 2.5m | 50 | Pigeon grass, mat rush, knotweed to waters edge | 50mm |
| 13 | E | Established riparian zone 35m, waterhousia, flooded gum, mat rush at waters edge, established mid storey | Vertical 1m, moderate 15m, steep 10m | 80 | Mat rush, BL paspalum, shrubs | 50 |
| | W | Riparian 7m wide, waterhousia, wattles, mat rush & knot weed on bank, fallen logs, woody debris | Vertical 1m, steep 2m | 75 | Knotweed, mat rush, basket grass, BL paspalum | 75mm |
| 14 | E | Cleared grassland, knotweed to water level | Steep 0.5m | 40 | Knotweed | Nil |
| | W | Riparian 7m wide, waterhousia, wattles, mat rush & knot weed on bank, fallen logs, woody debris | Vertical 1m, steep 2m | 75% | Knotweed, mat rush, basket grass, BL paspalum | 75mm |
| 15 | E | Cleared grassland, knotweed to water level | Vertical 1m | 55 | Pasture grass, knot weed | Nil |
| | W | Riparian, waterhousia, camphor, mat rush at water level (clumps) | Vertical 1m, moderate 2.5m | 70 | Mat rush, BL paspalum | 75mm |
| 16 | E | Cleared grassland, knotweed to water level | Vertical 1m | 55 | Pasture grass, knot weed | Nil |
| | W | Riparian, waterhousia, mat rush at water level | Steep 4m | 75 | Mat rush, BL paspalum, lantana | 50 |
| 17 | E | Cleared, grassland | Vertical 1m | 60 | Pasture grass, knot weed | Nil |
| | W | 8m riparian zone, waterhousia | Steep 4m | 65 | Mat rush, low shrubs | 50mm |
| 18 | E | Fragmented, grazed, half cleared, waterhousia, camphor | Moderate slope 2m | 40 | Knot weed, pigeon grass | 10mm |
| | W | Fragmented riparian, waterhousia, camphor, pigeon grass & knot weed on immediate bank | Steep, with back channel | 90 | Knot weed, pigeon grass | 20mm |
| 19 | E | Fragmented riparian vegt, waterhousia, flooded gum, grazed, cleared u/S | Sloping, moderate | 70 | Sparse mat rush, BL paspalum | 10mm |
| | W | Cleared grassland, dense pigeon grass | Steep, with back channel | 90 | Pigeon grass | 10mm |
| 20 | E | Fragmented riparian vegt, waterhousia, flooded gum, grazed, cleared u/S | Sloping, moderate | 70 | Sparse mat rush, BL paspalum | 10mm |
| | W | Cleared grassland, dense pigeon grass | Steep, with back channel | 90 | Pigeon grass | 10mm |
| 21 | E | Fragmented riparian vegt, waterhousia, grazed, cleared u/S | Sloping, moderate | 70 | Sparse mat rush, BL paspalum | 10mm |
| | W | Cleared grassland, dense pigeon grass | Steep, with back channel | 90 | Pigeon grass | 10mm |

**Table A3:** Habitat data collected in 8 zones at Butchers Creek

| Zone | Bank | Land use (E&W) | Broad veg community (E&W) | In-stream physical characteristics (logs, boulders etc) | Stream width | Stream depth | Presence of pools or riffles | Bed composition (%) | Emergent veg |
|---|---|---|---|---|---|---|---|---|---|
| 1 | N | Agriculture | Camphor forest | Pool/riffle with rocks | 3 | Nil | Nil | Rock 50%; litter 25%; vegt 25% | Mat rush |
| | S | Agriculture | Shrubs and | Pool/riffle with rocks | 3 | Nil | Nil | Rock 50%; litter 25%; vegt 25% | Mat rush |
| 2 | N | Agriculture | Grassland | Pool rifle with rocks | 3.5 | Nil | Nil | Rock 25%; litter 40%; grass 40% | Grass |
| | S | Agriculture | Wet sclerophyll | Pool rifle with rocks | 3.5 | Nil | Nil | Rock 25%; litter 40%; grass 40% | Grass |
| 3 | N | Agriculture | Wet sclerophyll | Pool/riffle with rocks | 3 | Nil | Nil | Rock 30%; litter 60%; silt 20% | Mat rush |
| | S | Agriculture | Disturbed grassland | Pool/riffle with rocks | 3 | Nil | Nil | Rock 30%; litter 60%; silt 20% | Mat rush |
| 4 | N | Agriculture | Wet sclerophyll | Pool/riffle with rocks | 4.5 | Nil | Nil | Rock 70%; gravel 10%; silt 10%; organic 10% | Nil |
| | S | Agriculture | Disturbed grassland | Pool/riffle with rocks | 4.5 | Nil | Nil | Rock 70%; gravel 10%; silt 10%; organic 10% | Nil |
| 5 | N | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 6 | Nil | Nil | Rock 60%; litter 40% | Nil |
| | S | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 6 | Nil | Nil | Rock 60%; litter 40% | Nil |
| 6 | N | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 6 | Nil | Nil | Rock 60%; litter 40% | Nil |
| | S | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 6 | Nil | Nil | Rock 60%; litter 40% | Nil |
| 7 | N | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 5 | Nil | Nil | Rock 60%; litter 40% | Nil |
| | S | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 5 | Nil | Nil | Rock 60%; litter 40% | Nil |
| 8 | N | Agriculture | Wet sclerophyll | Pool/ riffle with rocks | 6-7 | Nil | Nil | Rock 60%; litter 40% | Nil |
| | S | Conservation | Wet sclerophyll | Pool/ riffle with rocks | 6-7 | Nil | Nil | Rock 60%; litter 40% | Nil |

**Table A4:** Habitat data collected in 8 zones at Butchers Creek

| Zone | Bank | Stream bank characteristics | Bank profile | Bank vegetation cover (%) | Groundcover composition | Depth of leaf litter |
|---|---|---|---|---|---|---|
| 1 | N | Camphor, mat rush, lantana, privet, degraded | Vertical 1.25m | 60 | Mat rush, carex, lantana | 25mm |
| | S | Mat rush, Lilly pilly, privet, Brown kurrajong degraded | Steep slope 2m | 60 | Mat rush, BL paspalum, regrowth shrubs | <10mm |
| 2 | N | No o/S, grass & lantana | Vertical 1m | 90 | Pigeon grass, lantana | 20mm |
| | S | 2m wide, camphor, flooded gum, red ash, degraded | Vertical 2m | 60 | Mat rush, lantana, BL paspalum | 20mm |
| 3 | N | 3m wide, camphor, lantana, privet, highly degraded | Vertical 1.5m | 60 | Gahnia, mat rush, ferns, BL paspalum | 50mm |
| | S | 2m wide riparian zone, catacomb, lantana, degraded | Vertical 1.5m | 40 | Mat rush, gahnia, lantana, ferns | 25mm |
| 4 | N | 5m wide riparian zone, clumps of mat rush & gahnia, degraded | Vertical 2m | 75 | Gahnia, mat rush, ferns, BL paspalum | 50mm |
| | S | 2m wide riparian zone, Callicoma, lantana, degraded | Vertical 2m | 10 | BL paspalum | 25mm |
| 5 | N | Rocky substrate, dense cover of lantana, mat rush, BL paspalum | Sloping - steep | 90 | Mat rush, lantana, BL paspalum | 30-50mm |
| | S | Intact riparian zone, water vine, lantana, flooded gum, camphor laurel | Steep | 80 | Mat rush, lantana, BL paspalum | 50-100mm |
| 6 | N | 5-10m riparian, flooded gum, camphor laurel, dense midstorey | Steep | 75 | Occasional mat rush & ferns | 30-50mm |
| | S | 20m + riparian, various midstorey rainforest species | Moderate slope | 80 | Occasional mat rush & ferns | 30-50mm |
| 7 | N | 5-10m riparian, flooded gum, camphor laurel, dense midstorey | Steep slope | 80 | Very sparse, low shrubs | 50-75mm |
| | S | 20m + riparian, various midstorey rainforest species | Steep slope | 80 | Very sparse, low shrubs, mat rush | 50-75 |
| 8 | N | 5-10m riparian, flooded gum, blackbutt, camphor laurel, dense midstorey | Vertical 7m | 70 | Very sparse, low shrubs | <20mm |
| | S | 20m + riparian, various midstorey rainforest species, camphor laurel | Variable | 80 | Mat rush, lantana, BL paspalum, saw-sedge | 30-50mm |

# Appendix B: Other frog species recorded

**Table B1:** Other frog species detected during year one operational phase surveys. Lit = Litoria, C = Crinia, Lim = Limnodynastes, Upe = Uperolia, Pseud = pseudophryne.

| Site | Date | Frogs | Notes |
|---|---|---|---|
| Butchers Creek | 16/10/18 | Lit. fallax, C. signifera, Lit. gracilenta, A. brevis, Pseud. coriacea, Lim. peronii, Lit. nasuta, M. fasciolatus, Lit. barringtonensis, Lit. revelata, Lit. peronii, Lit. dentata | Lit. barringtonensis x 3, Lit. gracilenta x1 in culvert |
| Warrell Creek | 17/10/18 | Lit. dentata, Lit. fallax, Lit. gracilenta, C. signifera, Upe. sp. | |
| Butchers creek | 25/2/19 | Pseud. coriacea | |
| Warrell Creek | 25/2/19 | Lit. fallax, Lit. nasuta | |
| | 26/2/19 | Lit. fallax | |
| Butchers creek | 19/3/19 | Pseud. coriacea, Lim. peronii, C. signifera | |
| Warrell creek | 19/3/19 | Lit. gracilenta | |
| Warrell Creek | 20/3/19 | Lim. peronii, Lit. fallax | |

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